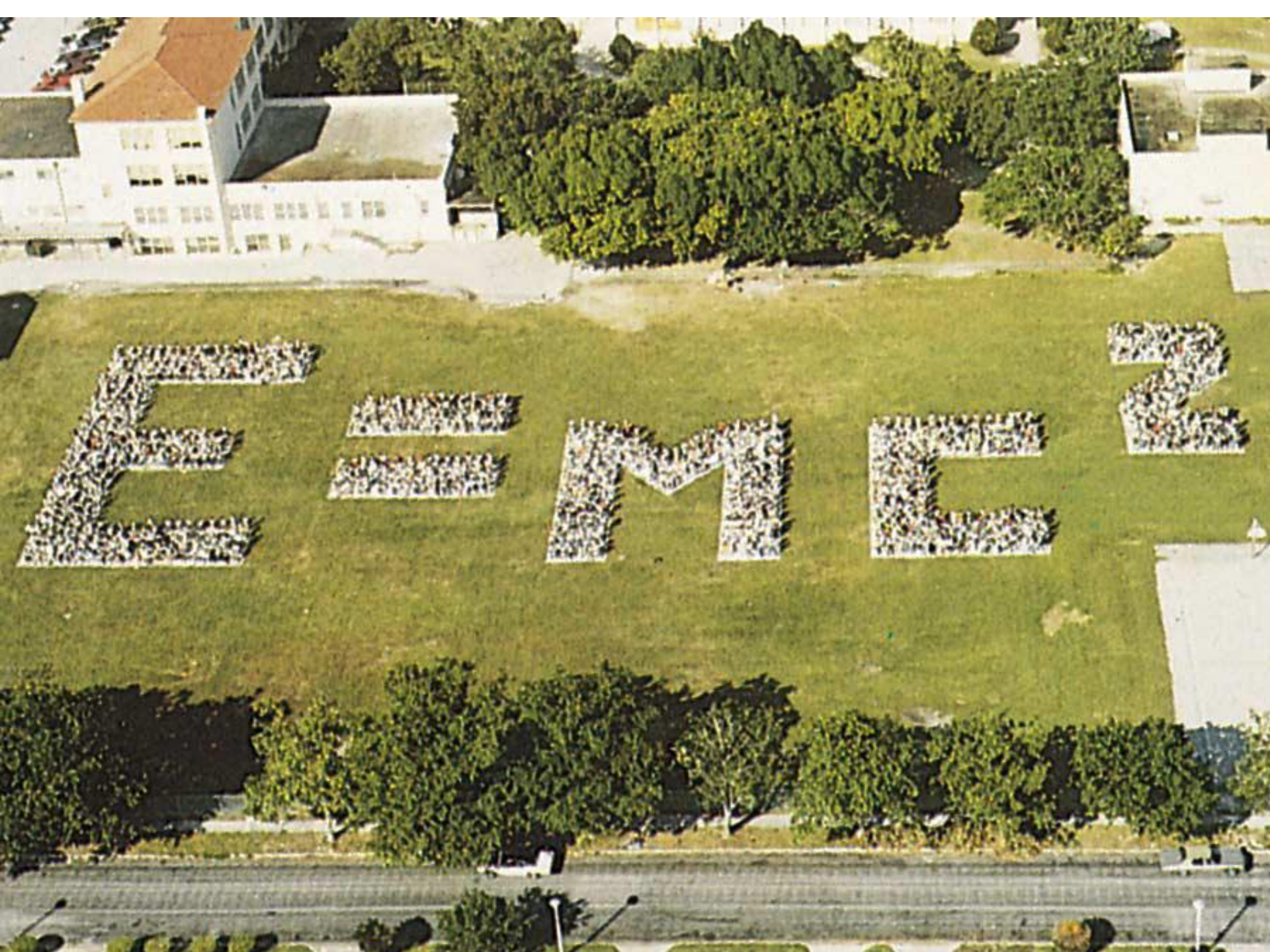
E=MC²

**Physics education at FTS CTU**

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Dept. of Applied Mathematics K611 – Florenc

Subject website – **https://zolotarev.fd.cvut.cz/fyze**

Two terms (semester) of education (11FYZ-E and 11EMO-E)

- Lecture
- Practical exercises (labs) – compulsory
- Seminary exercise (11SCF-E) – voluntary but recommended

**Lectures**

Thu 11:30 – 13:00 (B302, Horska building)

**Laboratory exercises: compulsory**

Thu 13:15 – 14:45 (B291c labs at Horska)

will start in the 1st week = today

opening exercise, lab safety rules, etc.

**Seminary exercises 11SCFZ-E: voluntary**

Thu 16:45 – 18:15 (A345, Horska) – another day / time ?

**Assessment conditions (by 16th February 2025)**

compulsory practical education (fully passed)

successful delivery of all measurement reports (A - E)

# Seminary exercise

## Supporting study literature

**Lectures:**

Halliday, D., Resnick, R., Walker, J.: Fundamentals of Physics (HRW)
pdf version at **http://libgen.rs/search.php**

**Laboratory exercises:**

subject website

**Seminary exercises:**

subject website

## Exam conditions

**final test of Seminary 11SCFZ-E** at the end of the term

4 problems – classification 0 – 2 points = **0 – 8 points total**

topics of the problems – see the website

if 5/8 points are reached = oral exam only

**Exams**

**written part** (if the test exam was not successful)

4 problems – classification 0 – 2 points = **0 – 8 points total**

if 5/8 points are reached = oral exam

**oral part –** 2 topics from the list of topics (available on the website)

# Pre-requisites of Physics

**High school / grammar school physics level knowledge**

physical quantities, units and basic laws
calculations without integration

**Definition of vectors and scalars**

direction of vector
components and magnitude of vector
addition and subtraction
dot product and cross product

**Basic knowledge of differential and integral calculus**

one variable

**Multivariable differential and integral calculus**

Stokes law, Green law, Gauss-Ostrogradsky law

# Simplification and Abstraction

**Abstraction of knowledge**

- separation of numbers and real objects
- substitution of numbers by symbols
- separation of properties and math objects

= **linear vector field**

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**Problem simplification –** based on the error extent

- description of the problem using measurable variables
- mathematical description and solution
- matching rate to the practical observation
- next iteration (if needed)

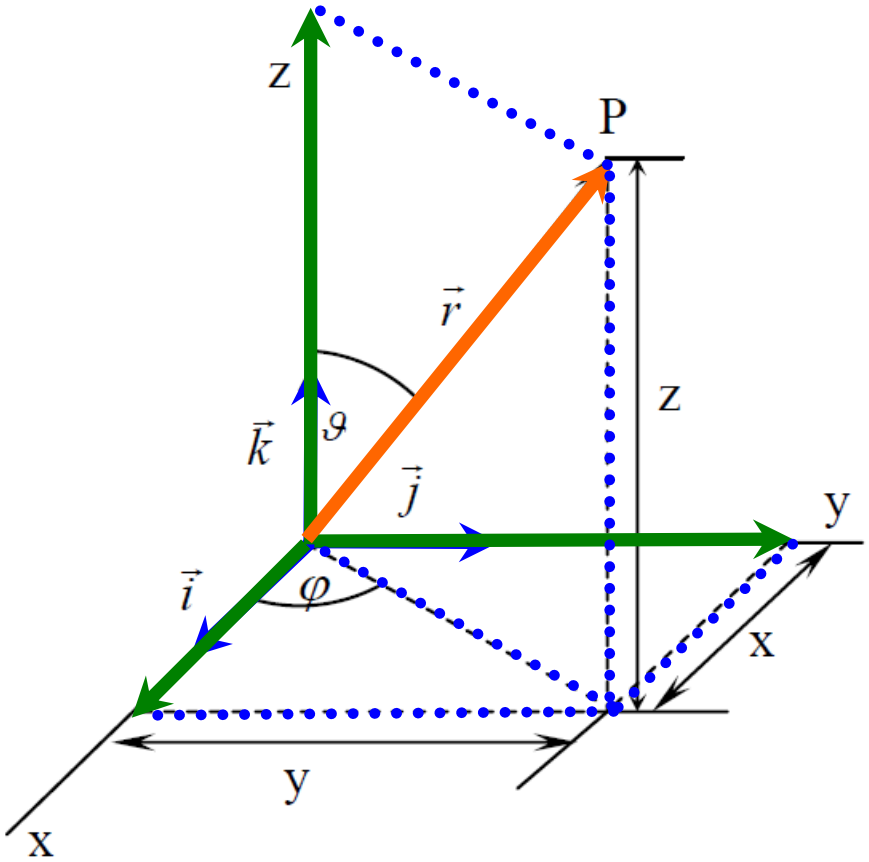
# Kinematics

# Mass point kinematics

## Mass point position

**Cartesian coordinates** $x, y, z$

**Spherical coordinates** $r, \vartheta, \varphi$ *(polar angle, azimuth)*




$$\vec{r} = x\vec{i} + y\vec{j} + z\vec{k}$$

$$r = |\vec{r}| = \sqrt{x^2 + y^2 + z^2}$$

# Displacement of the mass point

$$\vec{r} = x\vec{i} + y\vec{j} + z\vec{k}$$

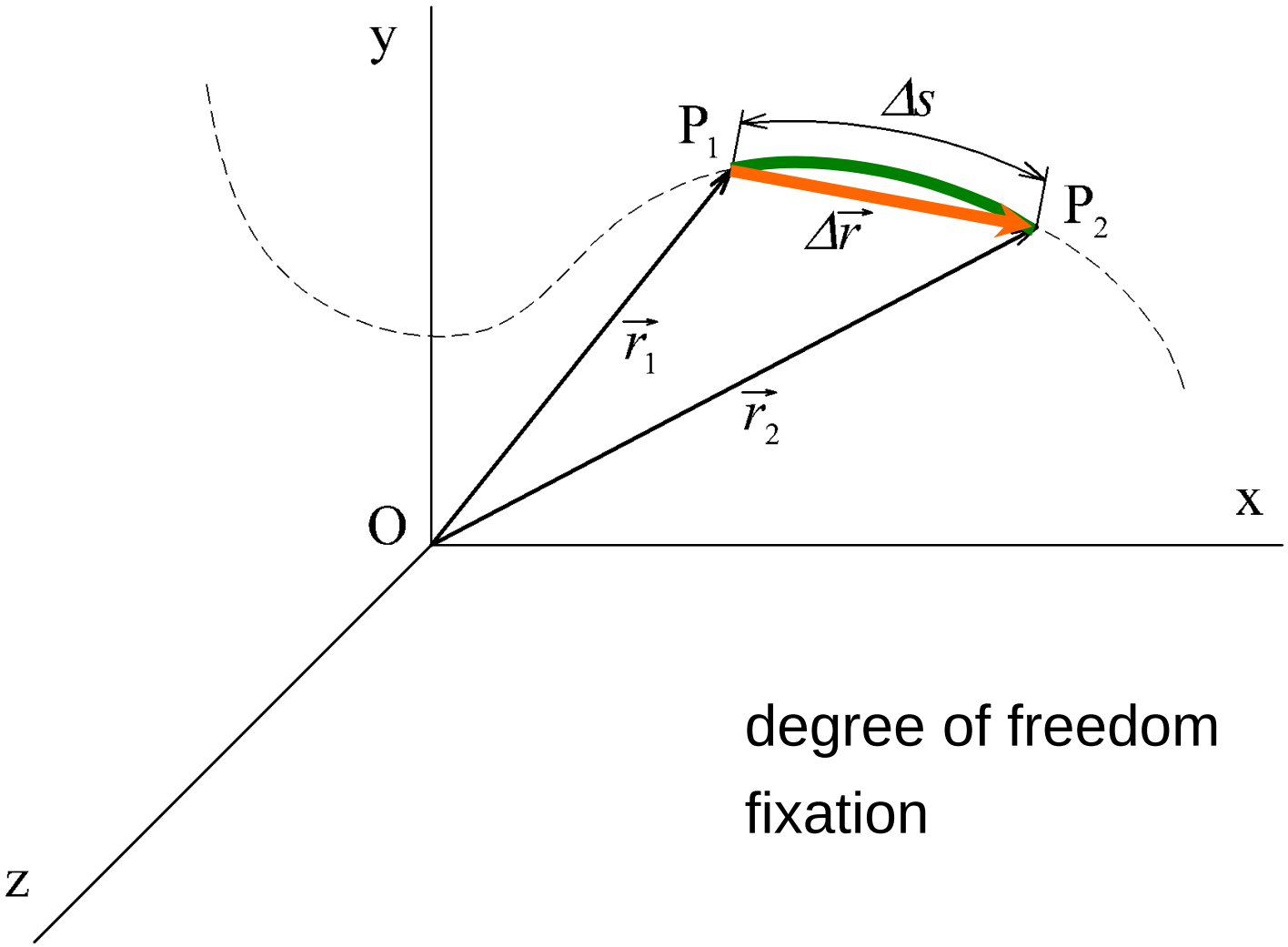
$$\vec{r} = \vec{r}(t)$$

$$x = x(t)$$

$$y = y(t)$$

$$z = z(t)$$

$$\Delta s \geq |\Delta \vec{r}|$$

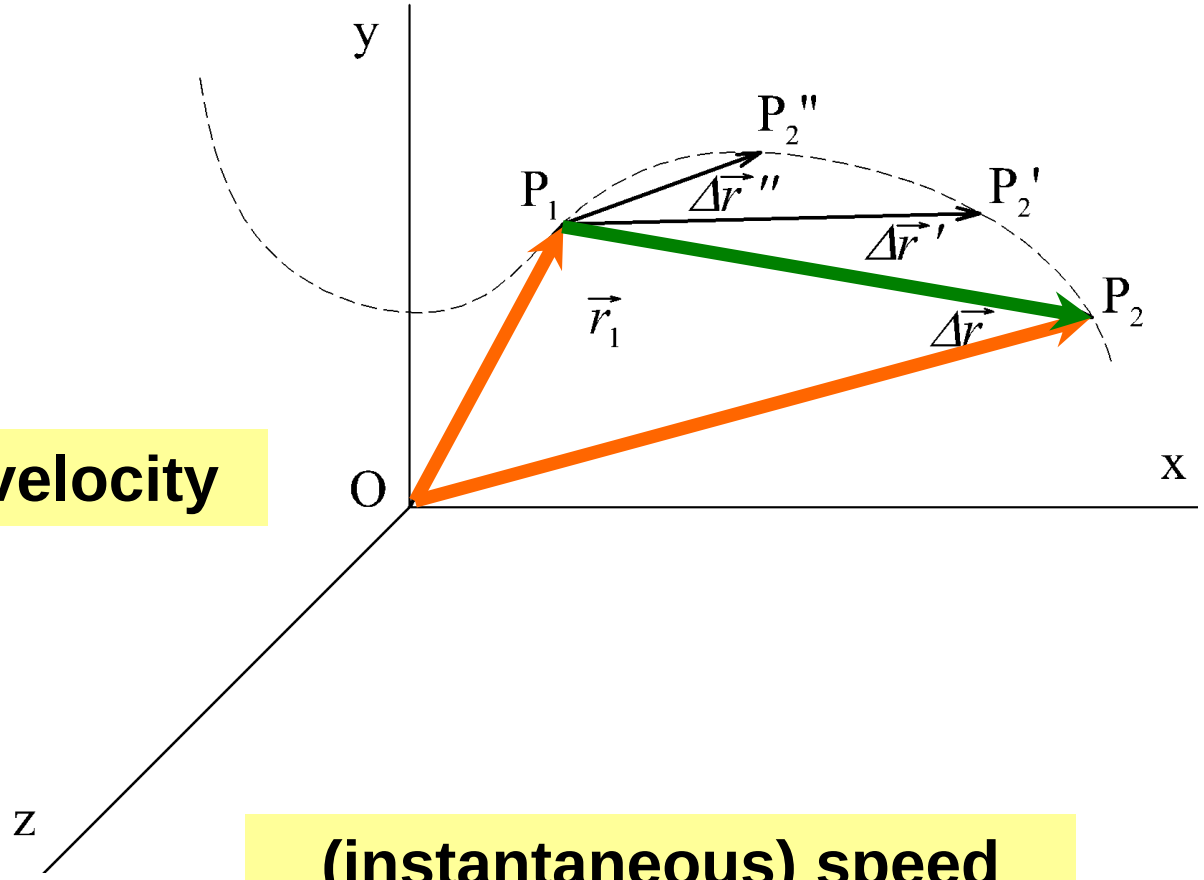



degree of freedom

fixation

## average velocity

$$\bar{\vec{v}} = \frac{\Delta \vec{r}}{\Delta t}$$




## (instantaneous) velocity

$$\vec{v} = \lim_{\Delta t \to 0} \frac{\Delta \vec{r}}{\Delta t} = \frac{d\vec{r}}{dt}$$

$$\vec{v} = v_x \vec{i} + v_y \vec{j} + v_z \vec{k}$$

## (instantaneous) speed

$$v = |\vec{v}| = \sqrt{v_x^2 + v_y^2 + v_z^2}$$

$$v_x = \frac{dx}{dt} \qquad v_y = \frac{dy}{dt} \qquad v_z = \frac{dz}{dt}$$

## mean acceleration

$$\bar{\vec{a}} = \frac{\Delta\vec{v}}{\Delta t} = \frac{\vec{v}_2 - \vec{v}_1}{\Delta t}$$

## (instantaneous) acceleration

$$\vec{a} = \lim_{\Delta t \to 0} \frac{\Delta\vec{v}}{\Delta t} = \frac{d\vec{v}}{dt}$$

$$a = |\vec{a}| = \sqrt{a_x^2 + a_y^2 + a_z^2}$$

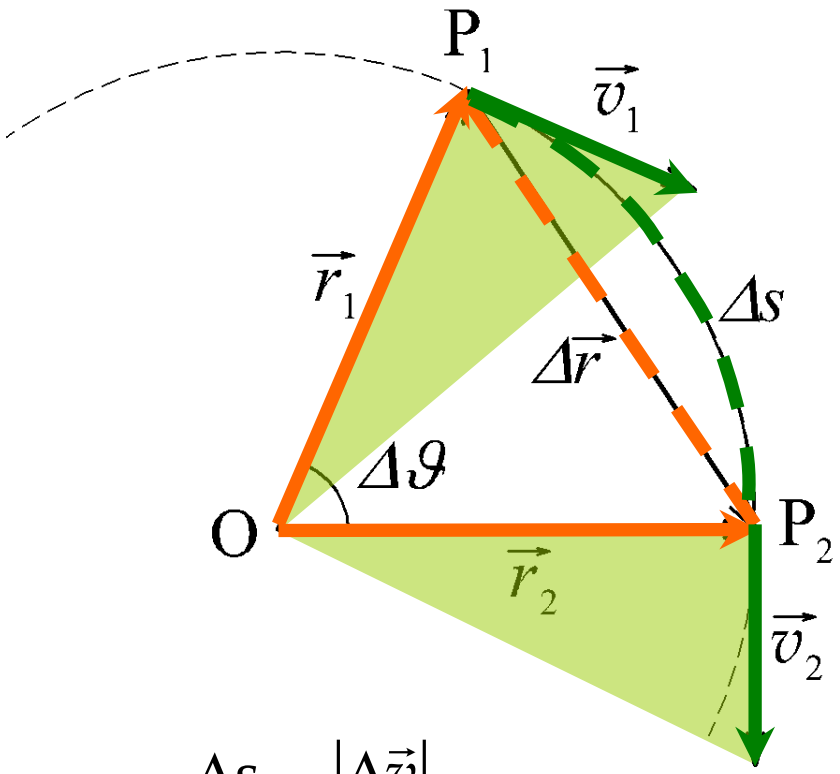
$$a_x = \frac{dv_x}{dt} = \frac{d^2x}{dt^2} \qquad a_y = \frac{dv_y}{dt} = \frac{d^2y}{dt^2} \qquad a_z = \frac{dv_z}{dt} = \frac{d^2z}{dt^2}$$

# Types of Motion

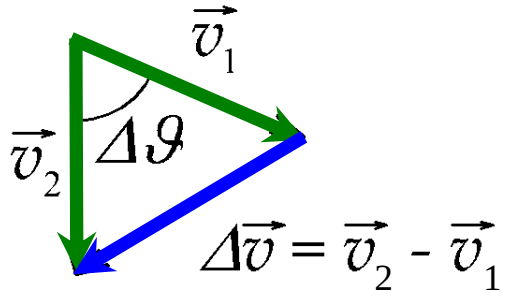
- straight-line, curved
- uniform, non-uniform

# Uniform circular motion

constant speed + trajectory with constant curvature




$$|\vec{r_1}| = |\vec{r_2}| = r$$
$$|\vec{v_1}| = |\vec{v_2}| = v$$




$$\Delta\vartheta = \frac{\Delta s}{r} = \frac{|\Delta\vec{v}|}{v}$$
$$\Delta s = v\Delta t$$

$$\frac{v\Delta t}{r} = \frac{|\Delta\vec{v}|}{v}$$

$$\frac{|\Delta\vec{v}|}{\Delta t} = \frac{v^2}{r} = a_n$$

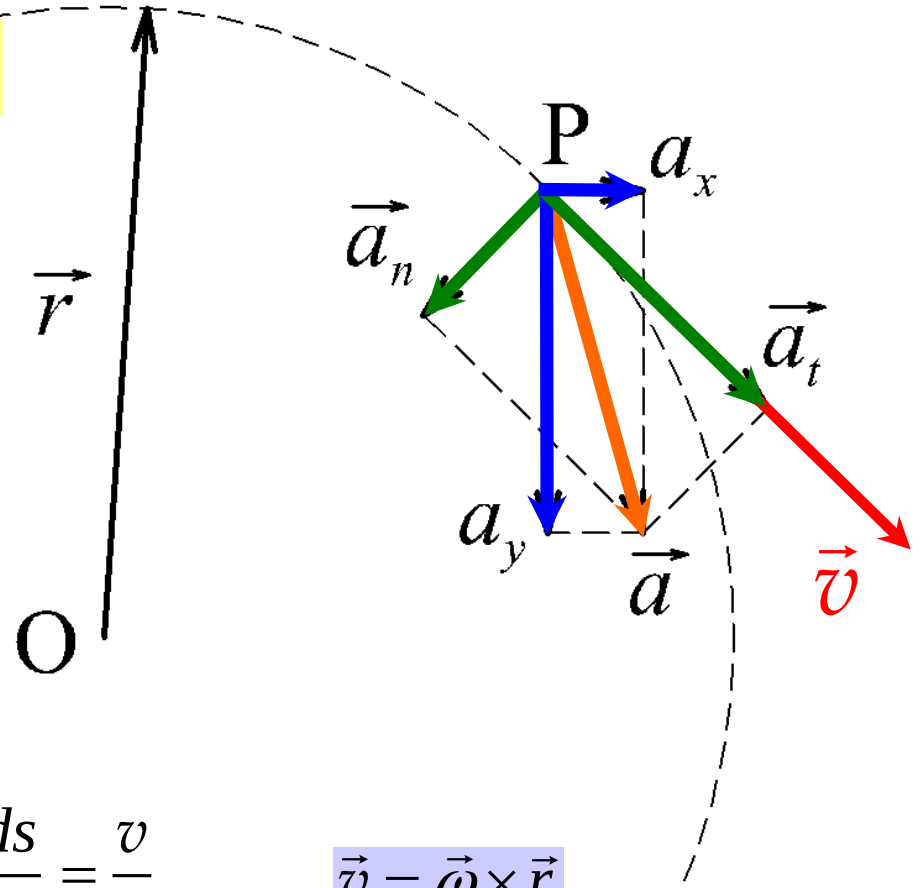
centripetal acceleration

# Non-uniform circular motion

$$\vec{a} = \frac{d\vec{v}}{dt} = \vec{a}_t + \vec{a}_n$$

$$a_t = |\vec{a}_t| = \frac{dv}{dt} \qquad a = \sqrt{a_t^2 + a_n^2}$$

$$a_n = |\vec{a}_n| = \frac{v^2}{r} \qquad a = \sqrt{a_x^2 + a_y^2}$$




angular velocity $\vec{\omega}$

$$\omega = \frac{d\varphi}{dt} \qquad \omega = \frac{d}{dt}\left(\frac{s}{r}\right) = \frac{1}{r}\frac{ds}{dt} = \frac{v}{r}$$

$$\vec{v} = \vec{\omega} \times \vec{r}$$

angular acceleration $\vec{\varepsilon}$

$$\varepsilon = \frac{d\omega}{dt} = \frac{d^2\varphi}{dt^2}$$

$$\omega = 2\pi f$$

$$f = \frac{1}{T}$$

# Galileo's theory of motion

$$\vec{r} = \vec{r}' + \vec{u}t$$

$$x = x' + |\vec{u}|t$$

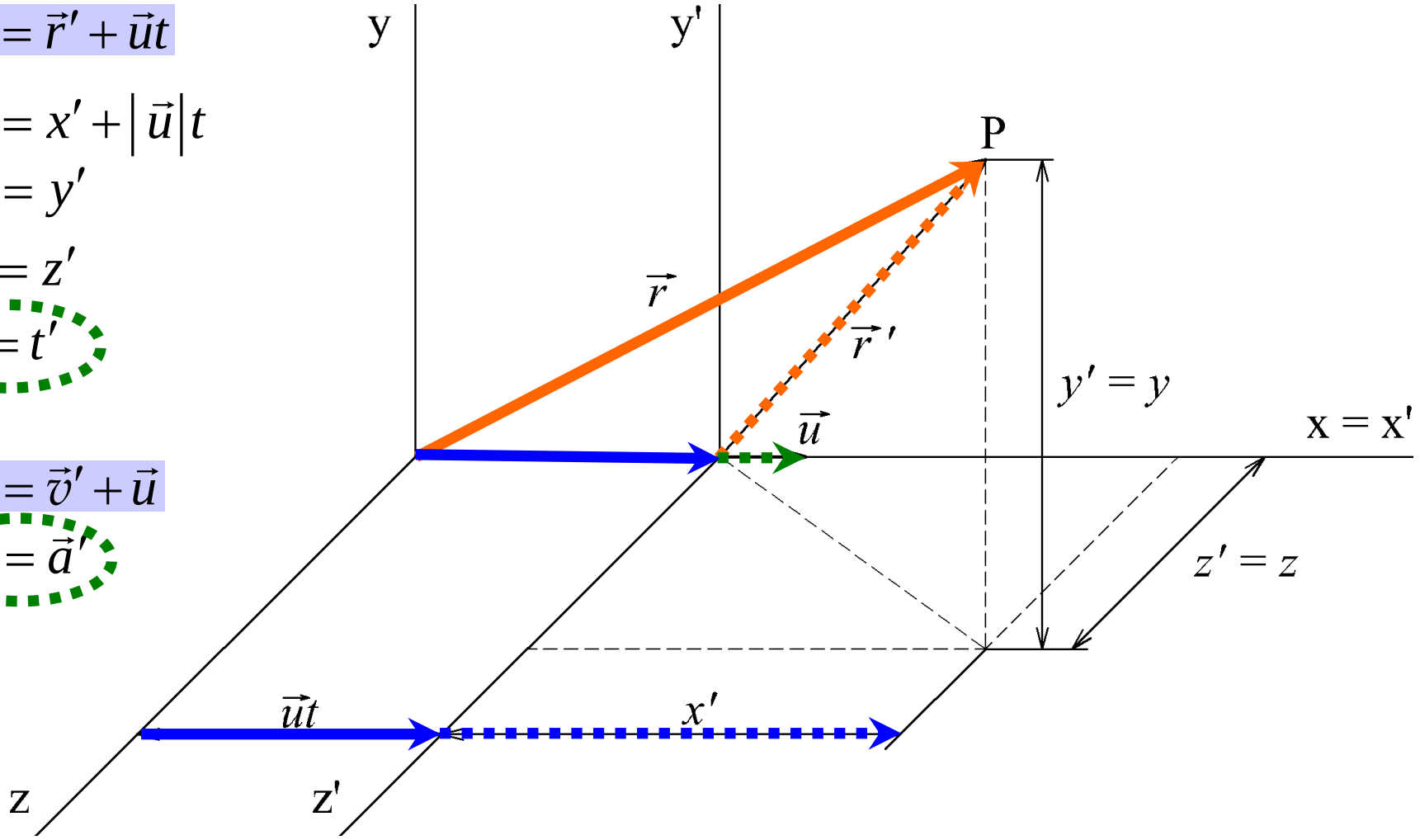
$$y = y'$$

$$z = z'$$

$$t = t'$$

$$\vec{v} = \vec{v}' + \vec{u}$$

$$\vec{a} = \vec{a}'$$




inertial reference frame – the acceleration is the same

# Lorentz factor

**STR postulate:**
the speed of light is the same in all inertial reference frames

$$x = \gamma(x' + |\vec{u}|t)$$
$$y = y'$$
$$z = z'$$

$$\gamma = \frac{1}{\sqrt{1-\beta^2}}$$

Lorentz factor

$$\beta = \frac{u}{c}$$

speed ratio

$$m = m'\sqrt{1-\frac{u^2}{c^2}}$$

**rest mass vs. relativistic mass**

$$x = \frac{x' + u t'}{\sqrt{1-\frac{u^2}{c^2}}}$$
$$y = y'$$
$$z = z'$$

$$t = \frac{t' + \frac{ux'}{c^2}}{\sqrt{1-\frac{u^2}{c^2}}}$$

$$v = \frac{v' + u}{1 + \frac{v'u}{c^2}}$$

GPS – time correction for the GPS satellites (precision of position)